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Gaspereau River alewife stock status report

Rapport sur l'état du stock de gaspareaux de la rivière Gaspereau

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ABSTRACT

The anadromous alewife (*Alosa pseudoharengus*) population of the Black River – Gaspereau River system in Nova Scotia supports both recreational and commercial fisheries of local importance. Both fisheries target adult alewife as they migrate upstream through the river and estuary to spawn in lakes during May-June. The 2001 assessment found that the Gaspereau River alewife population exhibited the characteristics of a heavily exploited stock. Exploitation rates were high, nearly 80%, and the majority of fish in the spawning run belonged to only 2 age classes. A five-year fishery management plan came into effect for the start of the 2002 season with the goal of meeting the spawning escapement target of 400,000 adults through a reduction in fishing mortality. Exploitation rates have been lower in every year since the implementation of the management plan (average c. 55%; range c. 52% to c. 63.9%) than the average exploitation rate reported in the last assessment (c. 79.5%). Spawning escapement has doubled since the implementation of the management plan, but has yet to reach the target of 400,000 alewives with the exception of 2003. There are no indications that either alewife longevity or incidence of repeat spawning has increased in response to the decrease in exploitation and changes in fish passage that came into effect concurrently in 2002. Recruitment to the Gaspereau River adult population can occur as early as age three, most do not mature until ages four and five, with full recruitment to the adult population (and fishery) at age six. Therefore, 2006 was the earliest year that a measurable positive response, in terms of increased recruitment, to the reduction in exploitation, could be anticipated. Recruitment of age four spawners in the most recent year was low. There may be cause for concern with post-escapement and/or post-spawning survival should these characteristics not increase. Further monitoring of stock size and age structure is warranted to evaluate the response to changes made in 2002.

RÉSUMÉ

La population de gaspareaux anadromes (*Alosa pseudoharengus*) de la rivière Black – réseau de la rivière Gaspereau, en Nouvelle-Écosse –, soutient des pêches récréatives et commerciales d'importance locale. Ces deux pêches visent les gaspareaux adultes qui remontent la rivière et l'estuaire pour aller frayer dans les lacs de mai à juin. L'évaluation de 2001 a révélé que la population de gaspareaux de la rivière Gaspereau affichait les caractéristiques d'un stock fortement exploité. Les taux d'exploitation étaient élevés, atteignant presque 80 %, et la majorité des poissons de la remonte n'appartenaient qu'à deux classes d'âge. Le plan quinquennal de gestion de la pêche entré en vigueur pour le début de la saison 2002 avait pour but de permettre des échappées de 400 000 géniteurs adultes en réduisant la mortalité par la pêche. Les taux d'exploitation annuels ont été moins élevés depuis la mise en œuvre de ce plan de gestion (moyenne d'environ 55 %; plage de 52 à 63,9 % environ) que le taux d'exploitation moyen indiqué lors de la dernière évaluation (environ 79,5 %). Bien que les échappées de géniteurs aient doublé depuis la mise en œuvre du plan de gestion, elles n'ont pas encore atteint la cible de 400 000 gaspareaux, sauf en 2003. Rien n'indique que la longévité des gaspareaux ou l'incidence d'un frai répété se soit accrues à la suite de la diminution du taux d'exploitation et des changements apportés aux passes à poissons qui ont aussi été apportés en 2002. Le recrutement dans la population adulte de la rivière Gaspereau peut survenir dès l'âge de trois ans, mais la plupart des poissons ne sont pas matures avant l'âge de quatre et de cinq ans; le recrutement complet dans la population adulte (et dans la pêche) survient quant à lui à l'âge de six ans. L'année 2006 a donc été la première année où l'on a pu s'attendre une réaction positive mesurable du recrutement à la suite de la réduction du taux d'exploitation. Au cours des dernières années, le recrutement des reproducteurs de quatre ans a été faible. La survie post-échappée et/ou post-fraie pourraient devenir préoccupantes si ces caractéristiques n'affichent pas de hausse. Il faut donc continuer à surveiller la taille et la structure par âges du stock afin d'évaluer sa réaction aux changements apportés en 2002.

INTRODUCTION

The anadromous alewife (*Alosa pseudoharengus*) population of the Black River – Gaspereau River system in Nova Scotia (Fig. 1) supports both recreational and commercial fisheries of local importance. Spawning runs of alewife and blueback herring (*Alosa aestivalis*) occur in many rivers of the Maritimes. Collectively they are referred to as gaspereau. The gaspereau stock in the Black River - Gaspereau River system is almost exclusively comprised of alewife, with only a very small number of blueback herring contributing to the fishery. Landings from the recreational fishery on the Black River – Gaspereau River are not reported but are not considered to be significant in comparison to the total annual harvest from the commercial fisheries. All fisheries target adult alewife as they migrate upstream through the estuary and river to spawn in lakes during May-June (Gibson and Myers 2001). Commercial fishing occurs with gillnets in tidal waters and with a weir and dip-net apparatus (Jessop and Parker 1988) - known locally, and defined in regulations, as a square-net - in non-tidal waters. There are 18 fishermen with commercial gaspereau licenses on this river; 16 square net licenses, 1 set gillnet license, and 1 drift net license. The fishing season begins on March 15th and closes May 30th.

Extensive modification to the Black River – Gaspereau River watershed has occurred during the past 80 years in order to facilitate hydroelectric generation (Jessop and Parker 1988; Gibson and Myers 2001). The original White Rock hydroelectric dam and fishway were constructed in 1919 and 1920, respectively. Further development involving the diversion of the upper reaches of the Black, Forks, and Gaspereau rivers and construction of several storage and power-generation dams began in 1930. See Jessop and Parker (1988) for more details. Currently, the water in over a dozen lakes interconnected by constructed canals and natural waterways (Fig. 1) is managed to provide water to five hydroelectric generating stations (Gibson and Myers 2001). Fish ladders, diversion screens, spillways and control gates are used by Nova Scotia Power Inc. (NSPI) to limit the impact of hydroelectric generation on alewife (and other species), most notably by facilitating access to spawning habitat and by diverting downstream migrating young-of-the year and post-spawned adults away from the five turbines located within the watershed (Fig. 1). The operation of many of the structures has been adjusted through time as the ecology of the fish populations has become better understood. Upgrades and changes in operations have therefore been ongoing. These include upgrades to the downstream bypass facilities at the powerhouse located in the lowermost dam at White Rock (Fig.2), upgrades to a fishway entering Gaspereau Lake, and replacement of the timber fishway at White Rock with a new concrete fishway at the main diversion dam, located approximately 2 km upstream of White Rock hydroelectric facility. The new fishway is accessed through a reopened section of the original river channel. These facilities have been in operation since prior to the 2002 spawning season.

The Black River-Gaspereau River alewife fishery has been formally assessed on two previous occasions, by Jessop and Parker (1988) for the years 1982 to 1984 and by Gibson and Myers (2001) for the years 1997 to 2000. A statistical catch-at-age/life history model was used by Gibson and Myers (2001) to generate biological and fishery reference points for the population using: 1) catch data available for the years 1964 to 2000, 2) biological data for the years 1982 to 1984, 1995, and 1997 to 2000 and 3) alewife counts at the White Rock fishway (Fig. 2) which represent escapement past the fishery, for the years 1970, 1982 to 1984, 1995, and 1997 to 2000. Spawning run size

averaged 537,000 fish (range: 265,000 to >1,082,000) and exploitation rates averaged 79.5% (range: 56.7% to 89.6%) during the years that escapement data were available (Gibson and Myers 2001). Spawner escapement in recent years had been only 10% to 20% of the escapement target estimated by Gibson and Myers (2001) as the spawning escapement that provides maximum sustainable yield (MSY), which corresponds to 400,000 to 450,000 spawners annually for this population.

The new fishery management plan came into effect for the start of the 2002 season with the goal of meeting the spawning escapement target of 400,000 adults through a reduction in fishing mortality. Following consultation with the commercial and recreational fishers, the normal weekly closed time of from 21:30h Friday to 05:30h the following Monday was amended to include an additional closure from 21:30h Tuesday to 05:30h Thursday in order to reduce potential fishing activity by about one fishing day. The additional closed day to fishing effectively reduced potential fishing activity a further 14% to 57%. The management goal and objectives of the plan are available in Appendix A.

This assessment updates the status of the Black River-Gaspereau River alewife stock, referred to hereafter as the Gaspereau River alewife stock, to the end of the 2006 fishing season. Estimates of annual abundance, escapement and exploitation rate as well as the biological traits of the runs in each year are presented. The methods used to estimate escapement since 2002 are presented for review. Biological characteristics of the annual spawning runs are presented to lend interpretation to the fisheries exploitation and spawner escapement information.

MATERIALS AND METHODS

CATCH DATA

Catch statistics for the Gaspereau River commercial alewife fishery, as was the case prior to 1986 for most of the commercial fisheries for diadromous species in the Maritime Provinces, were collected by Fishery Officers via sales slips (records of sales by individual fishers to commercial buyers) and by Supplementary A's and B's (Fishery Officer estimates of sales and personal uses, e.g., bait, not recorded by sales slips). These statistics have not been systematically collected in Maritimes Region since the implementation in 1986 of a mandatory fisher logbook program. The Gaspereau River commercial alewife fishery however represents a rare example within the Region where, up to the end of the 2005 season, local Fishery Officers continued to acquire annual harvest estimates as pail counts (see catch estimates from pail counts below) independently of that which is reported in returned logbooks by individual licence holders. The pail count data was previously used by Gibson and Myers (2001) to estimate both the number of fish in the catch and exploitation rate.

Although return of the logbooks within 30 days of the end of the fishing season has been a condition of licence since 1990, return rates from this fishery have averaged only 76% and have varied from 33% to 100% among years (Table 1). It is recognized that catch as reported in returned logbooks will likely be the sole basis for estimating catch from 2006 onward. However, this assessment continues the practice of using pail count data as the principle means to estimate catch (Fig. 3) for two reasons: (1) to maintain consistency with the 2001 assessment and; (2) for the purpose of evaluation of the changes in the

fishery and the alewife population following the regulated reduction in potential fishing activity that came into effect concurrently with the changes that occurred in fish passage, in 2002.

Catch estimates from pail counts

From 1964 to 2005, the total catch of alewives on the Gaspereau River was estimated by Fishery Officers by counting, during site visits to individual licence holders, the number of 50 pound pails into which the fish had been packed. Annual catch estimates for individual square- nets are available for the years 1978, 1980 to 1982, 1986, 1988, 1990 to 1993, and 1995 to 2005. The total annual pail count provided for the years up to 2001 were adjusted by the Fishery Officers to account for their estimate of the catch by gillnet fishers. The total annual pail count provided by Fishery Officers for the years 2004 to 2005 were each increased by 250 pails, the estimated annual catch by gillnet fishers for those years (F/O H. Sweeney, personal communication). It can be noted however that for the years that pail counts are available the reported annual catch for individual square-nets was lower on average by 511 pails, than the total annual catch provided by the Fishery Officers. Whether this is indicative of lower fishing success and/or participation in the gillnet fishery in recent years is not known.

The sole source of catch data for the 2006 season was catches as reported in returned logbooks. To be consistent with the method used in the last assessment to report catch, the 2006 season logbook catches had to be converted to pail counts. A conversion factor was created by comparing the reported logbook catch (kg) to the reported pail count data (converted to kg) from seven fishers who have consistently returned their logbooks every year since 1986. The mean weight of the converted pail count (7,484 kg ± 6,271 kg SE) for the seven fishers although 9.2% higher than the mean weight of their reported log book catch (6,872 kg ± 5,751 kg SE) for the same years are only marginally statistically significant (paired t-test = -1.8712, df=103, p-value= 0.0641 95 % CI: -1877.42488 54.56382). Therefore, the 2006 catch as compiled from returned logbooks was adjusted by the ratio of the mean of the converted pail counts (kg) over the mean logbook catch (2006 logbook catch (kg) multiplied by 1.089).

ESCAPEMENT COUNTS

White Rock Fishway (Years 1982 to 1984; 1997 to 2001)

Escapement counts and the methods of their acquisition, for all years prior to 2001, were reported by Gibson and Myers (2001) (Figs. 4-6). Counts were done by on-site personnel and generally acquired from 08:00h to 20:00h each day with occasional extension of the counting period to 24:00h during periods of heavy fish passage. Fish movement was halted at the end of each day by blocking the fishway with a screen until the next morning when counting would resume. Counts were generally recorded in 15-minute intervals; however, some were recorded in longer intervals during periods of low or sporadic fish movement. During these low periods, the fishway was blocked, typically from 30 minutes to four hours. Counting would resume once fish passage was restored.

The count for 2001 was acquired at the old fishway adjacent to the White Rock Power Facility (Fig. 2) as described above, and represents a complete count of all alewife that ascended the fishway in that year (Fig. 6).

New Fishway (Years 2002 to 2006) (adapted from Davies et al. In press)

Description of new facility

The fishway adjacent to the White Rock Hydro Facility, in use since 1980, was replaced prior to the 2002 alewife migration with a new concrete fishway located approximately 2 km upstream of the hydro facility (Fig. 2). The new fishway has a total of 47 pools, of which the lower 35 are connected via 1.2 metre-wide sloping apron weirs. The upper 12 pools are connected by a combination of submerged 0.4 m diameter orifices and 0.3 m wide surface weirs. Flow through the fishway varies between 0.21 and 0.28 cubic metres per second during the migration, and in response to headpond water levels.

A facility to count and sample upstream migrating fish species is located immediately upstream of the top of the fishway. Fish swimming out of the fishway are directed via incline and vertical screens into a flume suspended underneath the assessment facility. The flume area is accessible through a trap door. The flume, which is designed to reduce fallback and recession of migrating fish, directs the fish over an observation area where they are counted as they pass over a whiteboard installed on the bottom of the flume. A camera, triggered by motion detector software, is mounted directly over the viewing area to capture video of the fish as they swim through the field of view. Low level fluorescent lighting is used to illuminate the viewing area to improve contrast between the fish and the whiteboard underneath. A transparent, floating lexan box installed in the viewing area reduces surface turbulence.

Description of equipment

Video monitoring has been used since 2002 to record alewife counts through the fishway. A desktop computer is used to record MPEG-4 format video images of fish as they pass through the viewing area. Each frame of the stored video is time-stamped (day of year, hour, second). Motion detection software developed by Video Communication Research Incorporated (VCR Inc.) is used to limit recording to periods when fish were passing through the field of view of the camera. This reduced the amount of hard drive space used on days of light and/or sporadic fish movements and also the time required to review video and estimate spawning escapement. Each video file represents a 15-minute sample interval; however, the total length of time varies owing to the omission of the intervals when no motion through the viewing area was detected. Files were not created for sample units coinciding with zero fish passage. A two second recording buffer was set before and after motion detection was triggered.

Fish counts from stored video

All video for 2002 and 2003 was reviewed and a complete enumeration of the spawning run, with the exception of periods of equipment malfunction (Fig.7), was achieved. In 2002, equipment malfunction resulted in the loss of video for four days; however, visual counts were employed during this period thereby allowing for a complete count. In 2003, video monitoring began on May 6th and 309 fish were counted on the first data of monitoring. The low number of fish observed on the first day of monitoring suggests that a small number of fish may have utilized the fishway prior to May 6, leaving open the possibility that a portion of the early run may not have been censused. However, in light of the low number of fish observed on the first day there is reason to expect that few fish

were not counted. In 2003, a camera malfunction resulted in the loss of two complete days of counts, as well as intermittent loss of video throughout the run, sometimes during periods of heavy fish movement (Fig. 8). The malfunction was not immediately identified with the result that no visual counts were acquired for these periods.

From 2004 through 2006, *a posteriori* subsampling (Jessop and Harvie 1990; Davies et al. in press) of video was used to estimate total fish passage (Fig.9). Subsampling was of a stratified-by-day random design and achieved predicted levels of precision of approximately 10, 17 and 15% of the true run sizes with 95% confidence for the years 2004, 2005, and 2006 respectively. A total of 16 (year 2004), 7 (year 2005) and 8 (year 2006), 15-minute sample units, selected at random from each day of the annual run were required to meet these levels of precision. It should be noted that, in 2005, a total of 64 fish were estimated to have ascended the fish ladder on May 4, the first day of video monitoring. Fish may have ascended the fish ladder prior to this date. However, in light of the low number of fish observed on the first day there is reason to expect that few fish were not counted.

In addition to motion detection software being active, recording of video only occurred between 05:30h to 22:00h after 2003, since video monitoring indicated that more than 99% of the total run occurred during this period (Davies et al. in press). Escapement estimates and levels of precision assume that motion detection software was 100% effective in detecting fish and fish were counted without error. No correction was made to account for fish that may have ascended the fish ladder outside the recording times.

Interpolation of fish counts for days without video records

Linear interpolation of run size on the days bracketing the days of equipment malfunction was used to estimate the run of fish on the days with missing counts. Simulations by Davies et al. (In press) showed that, on average, linear interpolation resulted in small biases (less than 0.2%) when a single day was missing. However, if the lost day was a peak run day, or a missed day had low fish passage but was flanked by peak run days, the bias to the run estimate could be as high as 20%. Inspection of the data for the years 2002-2006 indicates that missed days were likely not peak run days, although verification is not possible. No evaluation of the potential bias associated with the linear interpolation method was done when more than a single consecutive day was missing (which occurred in 2003, 2004 and 2006). Consequently, the precision of escapement estimates for these years is likely lower than the estimates reported on figures 7 and 9.

In 2003, complete enumeration of the run was attempted; however, intermittent equipment malfunction in 2003 resulted in the loss of portions of video during periods of heavy fish movement. Linear interpolation was employed to estimate fish passage when the total amount of video lost for each day exceeded 30% (Fig. 8). No estimate of precision was done for 2003.

EXPLOITATION RATES

Exploitation rates were calculated for each year where both fish counts and commercial catch were available as:

$$Exploitation\ rate = \frac{catch}{stock\ size}$$

where stock size is the sum of number of fish caught (estimated from pail counts) and the annual escapement (number of fish) based on the counts at the fish ladder. The average number of fish per 50 lb pail for the years 2001 through 2006 was estimated using the mean weight per alewife during the fishery. For the years 2001, 2002 and 2006, mean weight was calculated from the alewife sampled daily and at random as they ascended the fishway. The data were pooled for each week of the fishery. The mean weight of alewife for the season was estimated by weighting the weekly mean weights by the proportion of the total run that passed through the fishway for that week (Table 2). The biological characteristics of the commercial catch in a given week are assumed to not vary significantly from those of the fish that escape the fishery (and therefore sampled upstream of the fisheries) during that week.

For the years 2003 through 2005, a two-stage random stratified sampling design was adopted to collect biological characters of the run. Briefly, approximately 250 alewife were sampled three times per week. The record of samples is summarized in Table 3. Three and five length-stratified samples per 0.5 cm intervals were collected for fish less than, and greater than, 250 mm in length, respectively. Samples were then frozen for later processing for biological characteristics up to six months later. An equation to predict total weight from fork length was created by log transforming pooled weekly samples of both total weight and fork length and doing a linear regression analysis. Each fish from length frequency samples was assigned the median length of the length interval to which it belonged and a predicted weight was calculated. Mean weight per alewife during the entire fishery was then calculated by weighting the predicted mean weight for the week by the proportion of the run represented within each week of the fishery.

Fish samples that had been collected in the first two weeks of the 2003 alewife run, and subsequently frozen, were lost during a power failure. The mean weights for week 3 and 4 of the fishery were estimated using the methods described above. The mean weight of 273.8 g estimated for week 3 (Table 2) represents the second highest mean weight for any week of sampling during the years 2001 through 2006. In all years of sampling, mean weight decreased over time during the fishery. Therefore, the mean weight for week 3 was used as an estimate of mean weight for weeks 1 and 2.

Pail counts for 2001 to 2006 were converted to number of alewives in the catch (Table 4) using the weight conversions described above. Stock size and exploitation rate were calculated from the converted pail count data (Table 4).

BIOLOGICAL DATA

Biological data for the Gaspereau River alewife stock is available for the years 1982-1984 and 1997-2006 (Table 5). Data for the years up to 2000 inclusive was reviewed by Gibson and Myers (2001). The previous sampling regime, and the sampling regime employed in 2001 and 2002, retained 10 randomly drawn fish from every 1000 alewives that ascended the ladder each day of the run (Gibson and Daborn, 1997; Gibson 1999, 2000, 2001;Gibson and Myers 2001). For the years 2003 through 2005, biological sampling adopted a two-stage random stratified method described in the exploitation rates section of this document. In 2006, approximately 60 fish per day were sampled.

For all years with the exception of 2006, fork length and weight were measured, sex was determined and scales were retained to determine age and spawning history. In 2006, total length, rather than fork length was measured. For this year, total lengths were converted to fork lengths using linear regression equations for males only, females only, and sexes combined (Table 6) that were calculated using data collected from approximately 500 Gaspereau River alewife during 1983 (DFO, unpublished data). The frozen lengths of the 2003-2005 length-stratified samples were converted to fresh lengths using the conversion factor adopted for Margaree River, Nova Scotia alewife (Chaput et al. 2001):

$$\text{adjusted fork length (mm)} = (1.0143 \times \text{frozen fork length (mm)}) + 4.557$$

Age and spawning history were assigned previously for fish sampled up to year 2002. A total of 301, 290, 541, and 319 alewife were aged for the years 2003 through 2006 respectively. The age and spawning history of the fish were interpreted following the criteria adopted by the previous assessments. Although samples were collected in 2003, a large portion of the run had passed during the first two weeks. This is the portion of samples that were lost in the freezer during the power outage; therefore, it was not possible to assign age and spawning history for this portion of the run. The truncation of the age structure samples from this year are not considered to be representative of the entire 2003 run and were therefore omitted from further analysis.

Proportions at age of the 2004 and 2005 escapement counts were derived from age-length keys that incorporate the change in length during the course of the spawning run. Proportions at age for 2006 were determined by multiplying the total number of fish estimated each week by the relative age structure proportion calculated for that week (Table 7).

Inspection of the 2004 and 2005 length frequency data showed that the 'adjusted frozen' stratified sample length frequencies did not always replicate the stratified length sample acquired at the time of field collection. There appear to be at least two possible causes, first, the field acquired lengths were not always accurate, i.e., numerous frozen samples contained fish that were much larger than either the largest and/or smallest fish reported in the fresh sample. Second, the regression used to convert frozen lengths to fresh lengths was not specific to Gaspereau River alewife nor does it account for the length of time the samples were frozen prior to laboratory sampling. Partial compensation for these factors was attempted by grouping all samples by 1 cm increments. In some cases it was also necessary to re-assign fish from one length bin to an adjacent bin so that the length frequency reflected the range of the length frequency from the field measurements.

RESULTS

ESCAPEMENT, RUN SIZE, CATCH, AND EXPLOITATION

Annual escapement counts, total run size, catch and calculated exploitation rates are listed in Table 4 for all years that escapement counts were acquired. Daily escapement counts for 1982-1984 and 1997-2006 are presented in Figures 4-9. For the years 2003-2006, the escapement counts before and after interpolation for missing days are listed in Table 4. Run size and exploitation rates are calculated using both escapement count estimates and are also listed in Table 4. Beginning in 2004 *a posteriori* subsampling of video records was used to estimate escapement counts. 95% confidence intervals around the escapement estimates are included in Table 4 for 2004-2006.

BIOLOGICAL TRAITS

A summary of the biological characteristics for the stock is presented in Table 5. There has been no statistically significant change in any of the biological characteristics since the additional one day closure of the fishery that came into effect in 2002. Spawning remains dependent on primarily two year classes, 4 and 5 year olds. The percentage of repeat spawners has remained variable among years. A proportional increase in repeat spawners is not evident since the implementation of the management plan; however this summary statistic can be influenced by years when a strong year class enters the spawning stock. The numbers at age in the spawning run for each year since 1997 are presented in Table 7. The survivorship to 2006 of new recruits from 2005 was 10%. The recruitment of 4 year olds in 2006 in relation to the number of spawners in 2002 was 0.28. This is low in comparison to previous years in the time series available.

STOCK STATUS PRE- VERSUS POST 2002

The average annual catch of 3,430±1,079 (SD) pails for the five-years since 2002 is below the average catch of 3,993±2,004 (SD) pails for the years 1997-2001, which includes the year of reduced fishing activity because of flooding (2001), and for the years 1996-2000 (4,965±1,345 (SD) pails). All of these recent five-year averages are lower than the long term average catch of 7,413±5,476 (SD) pails for the years 1964 to 1996 (Table 8). Exploitation rate since 2002 using either partial fishway counts or including interpolation for days missed has averaged 55.2% and 53.6%, respectively, which is lower than the average exploitation rates for the years 1997-2001 (73.3%) and 1996-2000 (83.2%).

Although average total run size (Table 8) since 2002 is lower than for either the 1996-2000 or 1997-2001 periods, escapement has, on average, increased approximately two-fold.

There are no indications that either alewife longevity or frequency of repeat spawning has increased in the years since the reduction in 2002 in potential fishing activity (Table 5).

DISCUSSION

The previous peer-reviewed assessment found that Gaspereau River alewife exhibited the characteristics of a heavily exploited stock (Gibson and Myers 2001). The high exploitation rates, 83% on average for the years 1997 to 2000, were considered by Gibson and Myers (2001) to be a significant factor contributing to low spawner escapement in recent years (average of 111,822 fish). Gibson and Myers (2003) estimated a reference point for $F_{collapse}$ at 93% exploitation. Potential fishing activity was accordingly reduced by an additional 24 hours beginning in 2002, with the aim of increasing spawner escapement to 400,000 fish within five years. The exploitation rate has been lower than the 1997 to 2000 average in every year since (Table 4), and has been either near or below the F_{msy} -associated exploitation rate of 63% calculated for this stock (Gibson and Myers 2003) and the 65% that represents the current reference point for Maritimes Region alewife populations generally (Gibson and Myers 2003). Simulation model results in Gibson and Myers (2003) suggest targeting fishing at the exploitation rate of 42% at $F_{35\%}$ as a reasonable strategy for alewife in the Maritime Provinces. With the exception of 2001 when flooding decreased fishing activity, exploitation rates of the Gaspereau River alewife stock have been above this value.

While the average exploitation rate has declined to about 55% and the average escapement has increased by approximately a factor of two during the five years since the new fishery management plan came into effect, the management objective of 400,000 spawners has yet to be met with the possible exception of 2003 when as many as 435,000 alewife may have escaped the fishery. Factors potentially contributing to the slower than anticipated response of the population to reduced fishing mortality include the following. First, run sizes have been relatively low in the years since 2002. Total run size would, for example, need to be in excess of 880,000 fish in order for the ~45% of the alewife that escape the fishery on average to number in excess of 400,000. However, total run size has not exceeded 880,000 fish in any year since 2002, with the possible exception of 2003 when total run size was estimated to have exceeded 850,000 fish. The total run size every year since 2003 has not exceeded 500,000 fish (Table 4).

Second, although recruitment to the Gaspereau River adult population can occur as early as age three years, most of the members of a given year-class do not mature until ages four and five, with full recruitment to the adult population (and fishery) at age six years (Tables 5 and 7). The year 2006 was therefore the earliest year that a measurable positive response, in terms of increased recruitment, to the reduction in fishing activity, could be realistically anticipated. The proportion of age four alewife that recruited to the 2006 spawning run in relation to the number of spawners in 2002 was low (Table 7). Attention should be directed to the number of age five recruits in the 2007 spawning run.

First time spawners continue to dominate the adult Gaspereau River alewife population. Incidence of repeat spawning averaged 16.4% (min. 10.3%, max. 23.4%) from 2002 to 2006, a marginal increase from the 5-year average of 14.3% (min. 8.1%, max. 21.7%) for the years 1997 to 2001 (Table 5). The lack of evidence for an increase since 2002 in maximum adult age or an increase in mean age of repeat spawners (Table 5) may warrant particular attention during the next few years. There may be cause for concern with post-escapement and/or post-spawning survival should neither variable measurably increase, in response to the absolute reductions to fishing activity and to the improvements to downstream bypass facilities that came into effect concurrently in 2002.

SOURCES OF UNCERTAINTY

- Three separate sampling regimes were applied between 2001 and 2006 to acquire information on the biological traits of the annual runs of alewife to the river. Of these, only the 2001 run/sampling year replicated the sampling protocols used by Gibson and Myers (2001) to assess population status for the years 1997 to 2000, and to develop the escapement target. The change in sampling protocols may have influenced the precision of the estimates of numbers at age, spawning history, and total landed catch (i.e., pail to number of fish conversions based on fish weights).

MANAGEMENT CONSIDERATIONS

- The 14% reduction in potential fishing activity that came into effect in 2002 reduced the exploitation rate of the fishery to about 55% on average from the 83% for the years 1997 to 2000.
- Escapement past the fishery has increased on average by approximately a factor of two relative to the 1997 to 2000 period.
- Escapement remains below the five-year management objective of 400,000 spawners an outcome, which is partially attributable to low total run sizes and a minimal four to five year lag time in an observable response (i.e., an increase in recruitment).
- There are no indications that either alewife longevity or incidence of repeat spawning has increased in response to the absolute reduction in potential fishing activity and improvements to downstream bypass facilities, that came into effect concurrently in 2002.
- Concerns with the status of gaspereau (alewife and blueback herring) populations, and the fisheries they support, have been expressed by clients and stakeholders, at gaspereau advisory meetings held throughout Maritimes Region since 2004. These concerns may indicate a general decline in alewife status has occurred within the region since the last Gaspereau River alewife assessment in 2001. This assessment does not, and owing to data deficiencies, cannot incorporate broader regional considerations into the formulation of science advice. The potential role of in-river versus regional influences on population size (beyond fishing effects) and post-spawned survival can therefore not be evaluated at this time.

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TABLES

Table 1. Catch statistics as reported by Statistics Branch, fisher returned log books, reporting rate, fishery officer estimated pail counts, and pail counts converted to metric tons.

Year	Statistics Branch Catch (mt)	Logbook Reported Catch (mt)	Logbook Reporting Rate (%)	Fishery Officer Pail Count Estimates (mt)	Fishery Officer Pail Count Estimates - # of 50 lb pails
1957	143				
1958	33				
1959	95				
1960	49				
1961	188				
1962	189				
1963	118				
1964	252			181	8000
1965	166			127	5600
1966	168			109	4800
1967	71			45	2000
1968	144			109	4800
1969	141			100	4400
1970	143			91	4000
1971	206			154	6800
1972	176			127	5600
1973	301			217	9600
1974	374			308	13600
1975	458			387	17080
1976	643			453	20000
1977	551			426	18800
1978	605			470	20744
1979	248			190	8400
1980	134			89	4900
1981	53			45	1920
1982	52			50	2190
1983	53			31	1380
1984	62			55	2420
1985	50			39	1710
1986	272	148		209	9228
1987	337	130	86	261	11510
1988	73	73	71	25 (206)	[b] 1100 (9087)
1989	[a] 1944	200	85	280	12380
1990	432	186	41	174	7679

a - believed to be an error

b - estimate used in last assessment; number in parentheses is estimate acquired since last assessment.

Table 1. (continued)

Year	Statistic Branch Catch (mt)	Logbook Reported Catch (mt)	Logbook Reporting Rate (%)	Fishery Officer Pail Count Estimates (mt)	Fishery Officer Pail Count Estimates - # of 50 lb pails
1991	198	95	79	64	2816
c					
1992	45	45	83	75	3320
1993	72	72	92	133	5886
1994	149	149	88	182	8022
1995	171	171	100	180	7958
1996	78	78	100	136	5999
1997	63	64	79	115	5096
1998	61	61	80	63	2800
1999	61	61	77	108	4772
2000	82	82	73	139	6157
2001		11	33	26	1142
2002		48	81	94	4130
2003		58	64	112	4949
2004		23	59	64	2845
2005		32	63	52	2314
2006		56	79	66	2910

c – after 1991, the transition was made by statistics branch to use log book data to report the catch by fishing district

Table 2. The mean weights by week of sampled alewife that were used to convert pail weight to number of fish per 50 lb pail.

	2001		2002		2003		2004		2005		2006	
week	mean weight (g)	prop. of run	mean weight (g)	prop. of run	mean weight (g)	prop. of run	mean weight (g)	prop. of run	mean weight (g)	prop. of run	mean weight (g)	prop. of run
1	237.2	0.0731	271.4	0.2303	**273.8** *	0.1180	253.1	0.0869	274.1	0.0583	245.7	0.4642
2	221.9	0.4827	245.6	0.2145	**273.8** *	0.1654	243.1	0.5868	249.4	0.2248	223.9	0.3515
3	208.8	0.3677	224.6	0.3766	273.8	0.5638	234.1	0.1609	237.3	0.4961	222.4	0.1082
4	203.8	0.0765	221.6	0.1787	245.6	0.1528	227.7	0.1653	224.6	0.2207	219.3	0.0761
weighted by proportion of run (g)	216.8		239.3		269.5		239.9		239.4		233.5	

* Mean weights for week 1-2 in year 2003 estimated to be same as week 3.

Table 3. Dates and numbers of fish measured and kept for biological samples in 2003-2005 at the White Rock fish ladder.

Sample collection date	2003		2004		2005	
	samples retained	samples measured	samples retained	samples measured	samples retained	samples measured
May-06					51	251
7						
8						
9						
10						
11						
12			51	208		
13					48	253
14			48	209		
15						
16					45	248
17			44	213		
18						
19			41	146	41	204
20					42	250
21			60	203		
22						
23	47	250				
24						
25					32	71
26			45	201		
27						
28			42	109		
29						
30	41	257			42	211
31			46	204		
Jun-01					42	207
2			34	52		
3					39	205
4	41	253	36	67		
5						
6	47	249			33	201
7						
8					35	173
9			46	211		
10	28	60			35	201
11			47	211		
12	23	28				
13						
14					54	214
15						
16			16	19	40	210
Total samples	227	1097	556	2053	579	2899

Table 4. Yearly summary of catch estimates, escapement count at White Rock fish ladder, estimated run size, and exploitation rates. Estimated run size in parentheses is calculated using the interpolated estimates of escapement. Exploitation rates in parentheses are the rates calculated using the interpolated estimates of escapement.

Year	Reported Log Book Catch (kg)	Number of 50 pound pails	Catch Estimate (number of fish)	Escapement (number of fish)			Estimated Run Size (number of fish)	Exploitation Rate (%)
				Total counts	Partial count estimates	Interpolated count estimates [± CI]		
2006	56,053	3,171	282,589****		≥ 206,809	209,064 ± 35,540	≥ 489,398 (491,653)	≤ 57.7 (57.5)
2005	31,558	2,575	219,173****		≥ 256,633	265,705 ± 39,855	≥ 475,807 (484,878)	≤ 46.1 (45.2)
2004	22,605	3,106	268,820****		≥ 149,156	175,046 ± 17,504	≥ 417,976 (443,866)	≤ 64.3 (60.6)
2003	58,227	4,948	416,335****		≥ 379,511	435,832	≥ 795,846 (852,167)	≤ 52.3 (48.9)
2002	47,899	4,130	391,278****	310,746			702,024	55.7
2001	10,947	1,142	119,348****	238,842			358,190	33.3
2000	82,066	6,157	754,585**	98,883			853,468	88.4
1999	61,067	4,772	698,600**	81,326			779,926	89.6
1998	61,304	2,800	372,400***	171,639			544,039	68.5
1997	63,472	5,096	611,520*	95,443			706,953	86.5
1995	170,775	7,958	954,960*	126,933†			>1,081,893	<88.3
1984	NA	2,420	212,966**	111,100			324,066	65.7
1983	NA	1,380	150,408**	114,800			265,208	56.7
1982	NA	2,190	254,068**	50,400			304,468	83.4
1970	NA	4,000	480,000*	60,527			540,527	88.8

* assumed 120 alewives/pail

** number of alewives /pail adjusted by taking the mean weight in the year when the number of alewife per pail was counted, and found to be 120, divided by the mean weight in the year of interest, multiplied by 120

*** assumed 133 alewives/pail

**** number of alewives/pail estimated by mean weight/alewife

† partial count

Table 5. Summary of Gaspereau River alewife stock characteristics. NAs are included in year 2003 because of the lack of data to provide the complete age structure of the run.

														5-year averages	
Characteristic	**Units**	**1997**	**1998**	**1999**	**2000**	**2001**		**2002**	**2003**	**2004**	**2005**	**2006**	**1997-2001**	**2002-2006**	**p-value**
mean fork length (SD)	**mm**	260 (38.6)	251.7 (15.98)	248.1 (11.67)	257.2 (13.18)	252.7 (12.14)		254.5 (12.35)	263.9 (4.56)	261.6 (3.92)	250 (4.32)	262.5 (17.22)	253.9 (4.7)	258.5 (6.0)	0.2186
max fork length	**mm**	315	302	286	311	299		310	288	315	296	319	302.6 (11.3)	305.6 (13.1)	0.7091
mean weight (SD)	**g**	236.6 (38.6)	226.5 (49.03)	208.5 (32.99)	245.4 (39.35)	216.3 (35.94)		238.9 (48.58)	267.6 (13.1)	234.3 (9.25)	232.2 (13.02)	227.1 (43.16)	226.7 (14.9)	240.0 (16)	0.2089
mean age (SD)	**y**	4.4 (0.68)	4.4 (0.59)	4.4 (0.52)	4.7 (0.56)	4.2 (0.72)		4.1 (0.62)	NA	4.4 (0.59)	4.2 (0.54)	4.5 (0.57)	4.4 (0.2) *	4.3 (0.2)	0.3582
max age	**y**	7	7	6	6	7		6	7	6	7	7	6.6 (0.5)	6.6 (0.5)	1
mean age 1st spawners (SD)	**y**	4.1 (0.38)	4.2 (0.39)	4.3 (0.47)	4.7 (0.54)	4.1 (0.64)		3.8 (0.42)	NA	4.3 (0.54)	4.1 (0.36)	4.4 (0.51)	4.3 (0.2) *	4.1 (0.3)	0.479
mean age repeat spawners (SD)	**y**	5.4 (0.63)	5.2 (0.51)	5 (0.27)	5.3 (0.44)	5.1 (0.78)		4.9 (0.54)	NA	4.9 (0.54)	5.3 (0.65)	5.2 (0.39)	5.2 (0.2) *	5.1 (0.2)	0.3588
% repeat spawners	**%**	19.8	21.7	13.4	8.5	8.1		19.4	NA	23.4	10.3	12.7	14.3 (6.3) *	16.4 (5.9)	0.6271

Table 6. Regression equations (developed from fork length and total length measurements of alewives sampled from the Gaspereau River in 1986) used to predict fork length (FL) from total length (TL) for samples collected in 2006.

Sex	Regression Equations	R^2	p-value
Female	**FL** = 0.8826***TL** + -0.3612	0.97	<0.001
Male	**FL** = 0.8696***TL** + 3.2004	0.98	<0.001
Unsexed	**FL** = 0.8792***TL** + 0.5572	0.98	<0.001

Table 7. Annual numbers at age for the Gaspereau River alewife run. First number in the age indicates total age; second number indicates age at first spawning.

age	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
3.3	837	792	474	981	34,912	47,519	-	5,576	5,341	840
Total 3 year olds	837	792	474	981	34,912	47,519	-	5,576	5,341	840
4.3	624	1796	163	0	4,289	10,921	-	5324	2,502	0
4.4	64,827	112,947	48,965	30,872	131,509	198,661	-	79,809	201,358	87,340
Total 4 year olds	65,451	114,744	49,128	30,872	135,798	209,582	-	85,133	203,860	87,340
5.3	200	771	955	803	0	610	-	2,522	119	0
5.4	9,926	25,782	9,143	5,370	8,387	40,715	-	27,918	15,118	20,191
5.5	10,869	21,936	20,994	56,472	51,810	5,613	-	42,010	22,455	94,839
Total 5 year olds	20,995	48,489	31,092	62,646	60,197	46,939	-	72,450	37,691	115,030
6.3	0	0	0	204	959	0	-	0	0	0
6.4	3,470	2,737	476	201	897	2,574	-	1,737	4,335	359
6.5	3,692	4,106	156	1,758	4,100	4,132	-	749	3,863	2,915
6.6	200	386	0	2,172	1,531	0	-	0	983	359
Total 6 year olds	7,361	7,228	633	4,334	7,487	6,706	-	2,486	9,181	3,633
7.3	0	0	0	0	0	0	-	0	136	0
7.4	0	386	0	0	0	0	-	0	174	0
7.5	798	0	0	0	448	0	-	0	262	249
Total 7 year olds	798	386	0	0	448	0	-	0	572	249
Total	95,443	171,639	81,326	98,833	238,842	310,746	-	165,646	256,646	207,092
% new recruit	80.4%	79.3%	86.6%	91.6%	92.0%	81.0%	-	76.9%	89.7%	88.5%
Major YC	1993	1994	1995	1995	1997	1998	-	2000	2001	2001
Age	4	4	4	5	4	4	-	4	4	5
% of Total	68.6%	66.9%	60.4%	63.4%	56.9%	67.4%	-	51.4%	79.4%	55.5%
survivorship of new recruits from year t-1 to year t	-	41.3%	7.0%	10.1%	18.5%	25.4%	-	-	16.9%	10.0%
recruitment of 4 year olds in year t in relation to spawners in year t-4	-	-	-	-	1.38	1.16	-	0.81	0.84	0.28
recruitment of 5 year olds in year t in relation to spawners in year t-5	-	-	-	-	-	0.06	-	0.52	0.23	0.40

Table 8. Long-term mean catch, and 5-year means of catch, escapement, total run size, and exploitation rate for the 5 years prior to and post implementation of the management plan for the Gaspereau River alewife fishery.

	Catch		Escapement		Run Size		Exploitation Rate	
Time Period	Pails ±SD	number of fish	number of fish		number of fish		%	
1964-1996	7,413±5,476		-		-		-	
1997-2001	3,993±2,004	511,291	137,227		648,515		73.3	
1996-2000	4,965±1,345	609,276	111,823		721,097		83.2	
			Partial	Interpolated	Partial	Interpolated	Partial	Interpolated
2002-2006	3,430±1,079	315,639	260,571	279,278	576,210	594,918	55.2	53.6

FIGURES

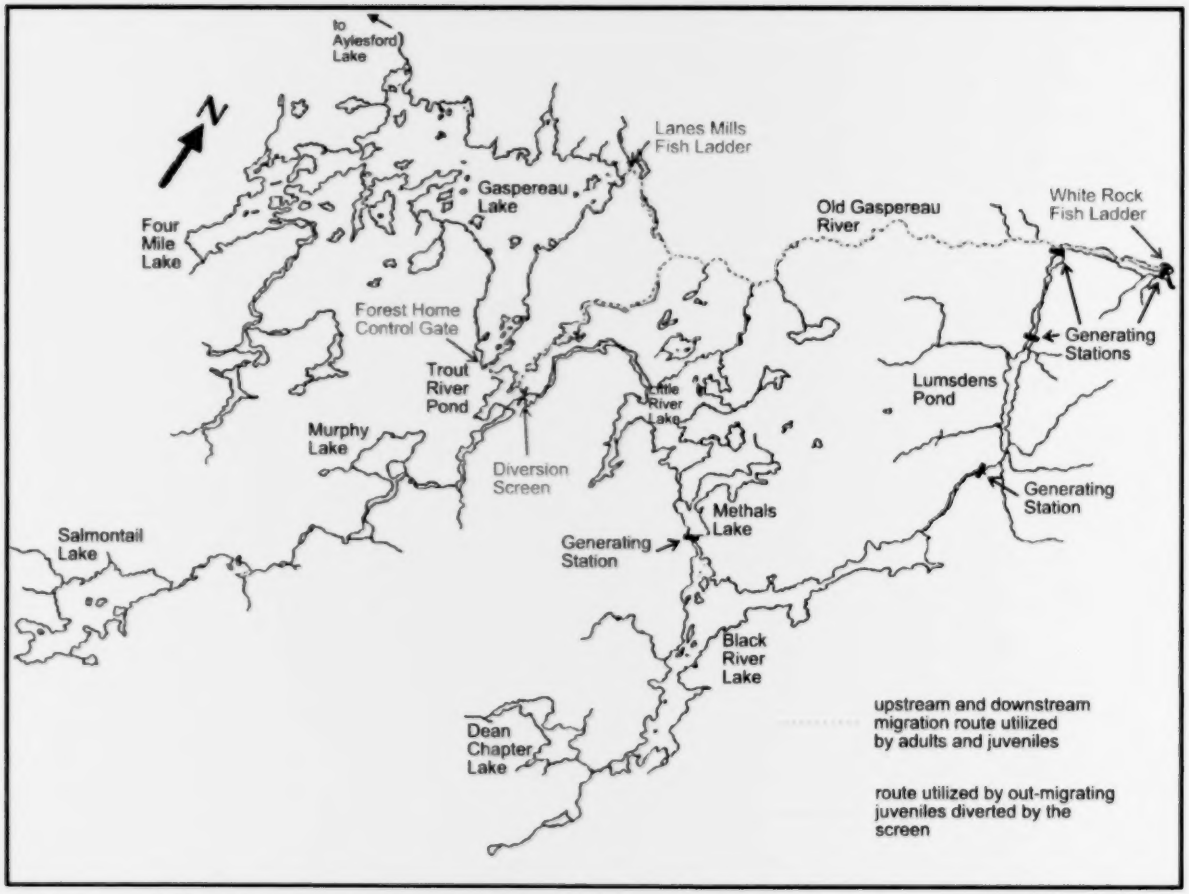

Figure 1. Partial map of the Gaspereau River watershed showing migration routes used by alewives (from Gibson and Myers 2001).

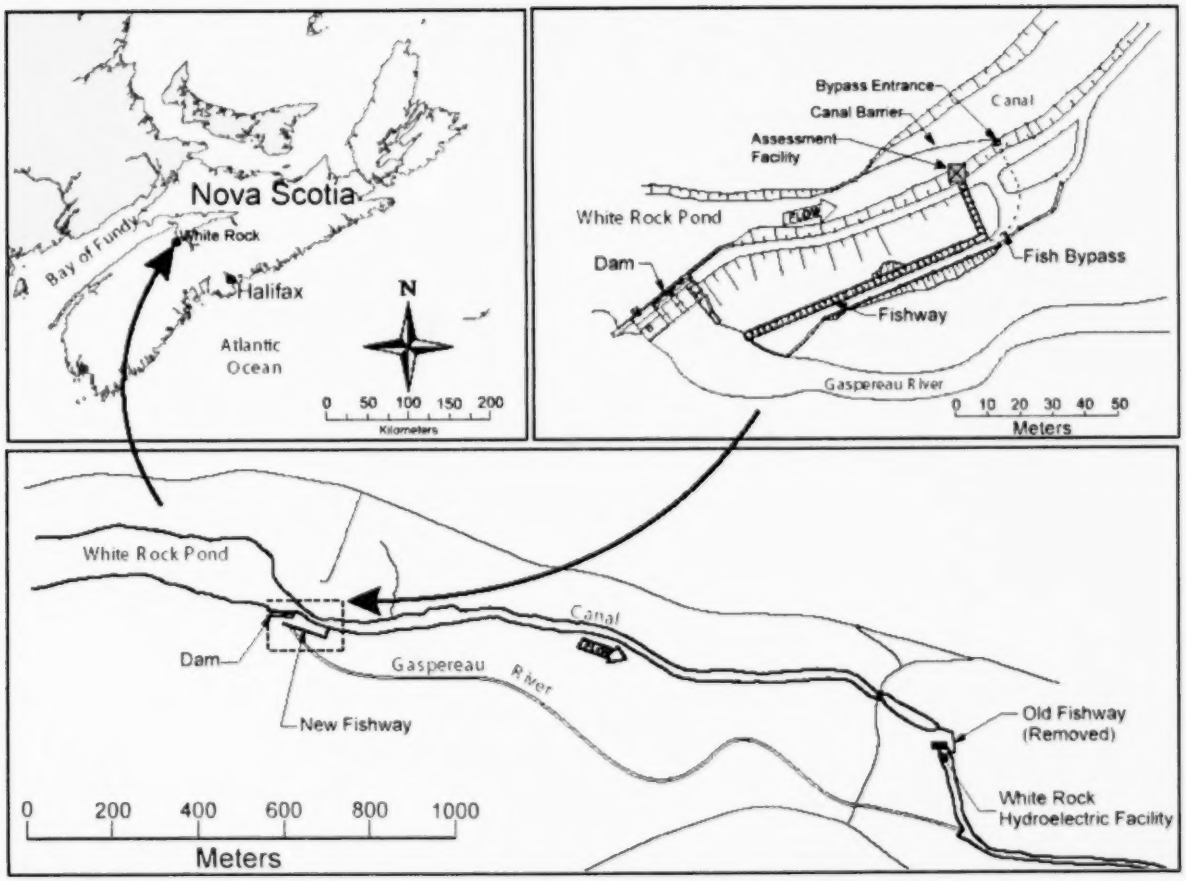

Figure 2. Map showing the location of the new and old fishways on the Gaspereau River, at White Rock, Nova Scotia, Canada (Davies et al. in press; used with permission).

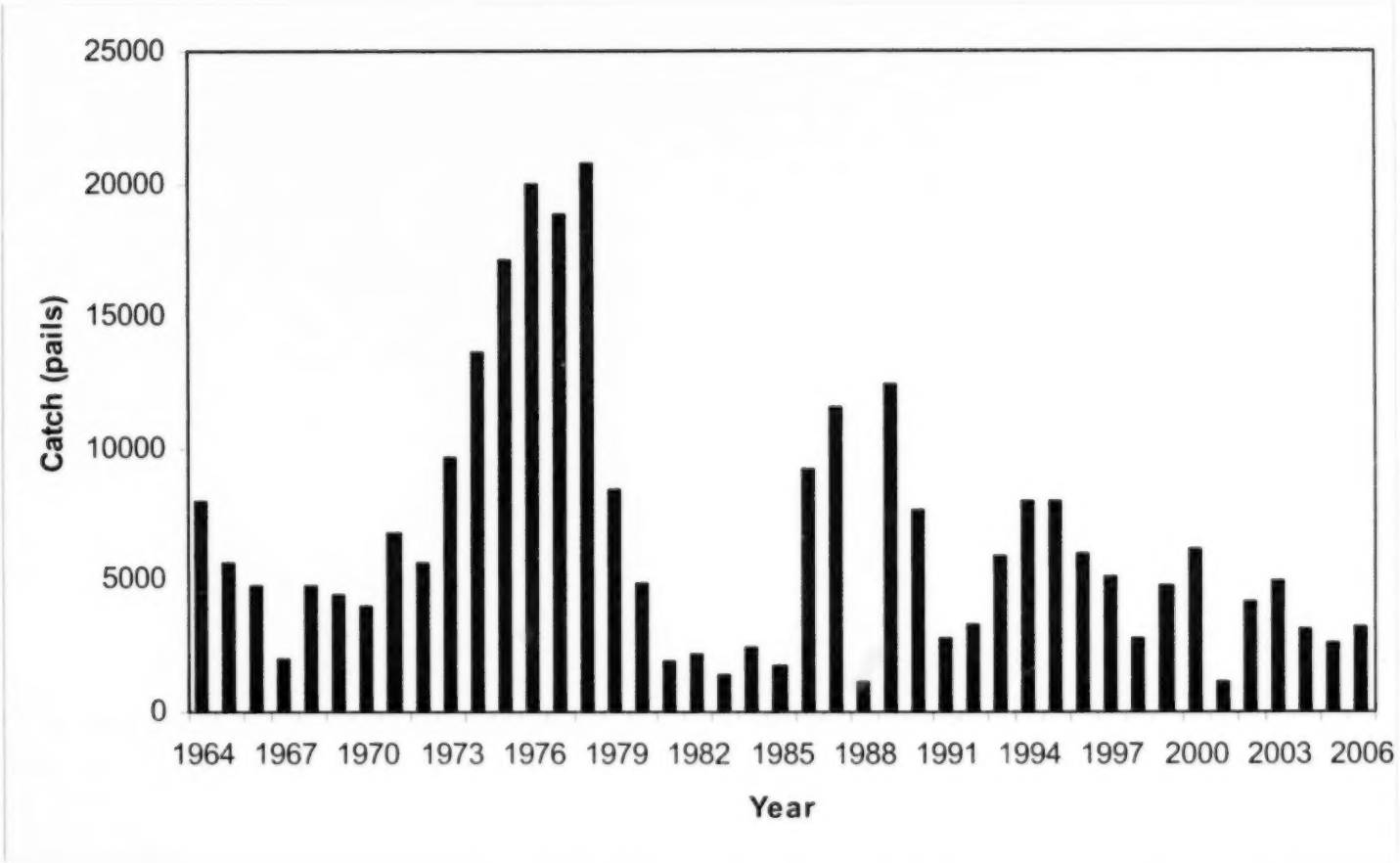

Figure 3. Catch estimates of alewife on the Gaspereau River from 1964-2006 (one pail contains between 100 and 133 fish).

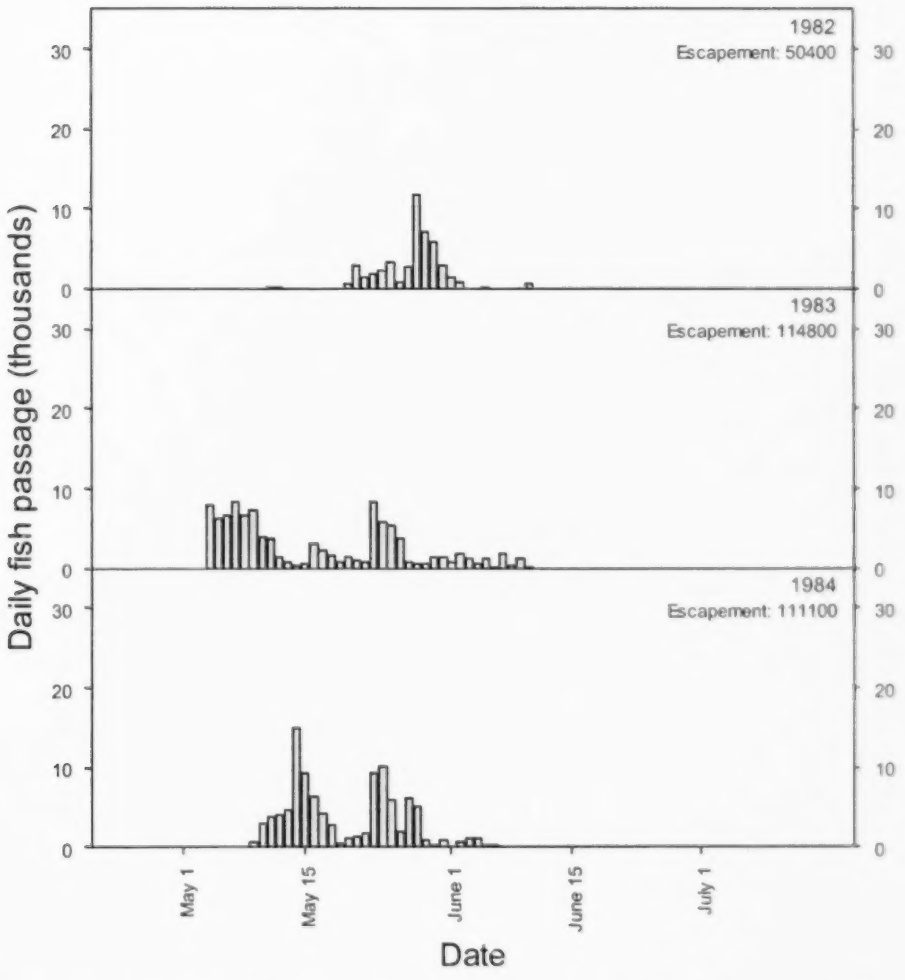

Figure 4. Daily escapement counts at the old White Rock fish ladder for the years 1982 to 1984. Visual counts were performed by field personnel and are total counts of the escapement run.

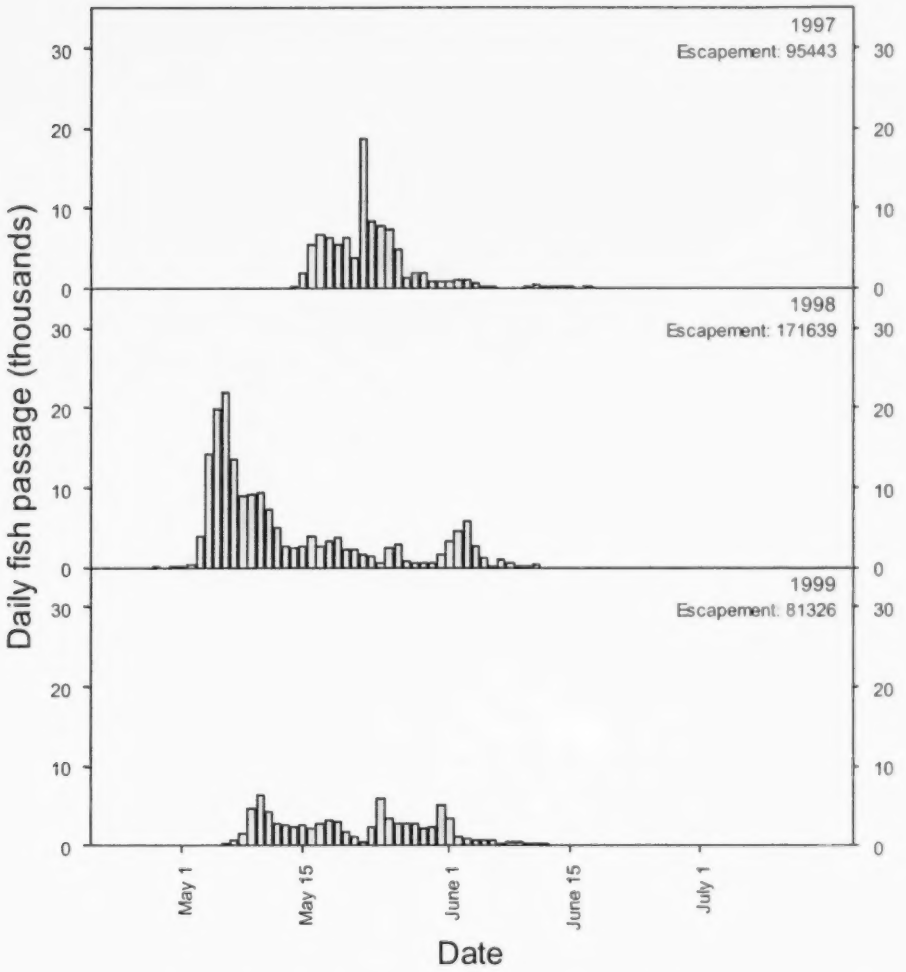

Figure 5. Daily escapement counts at the old White Rock fish ladder for the years 1997 to 1999. Visual counts were performed by field personnel and are total counts of the escapement run.

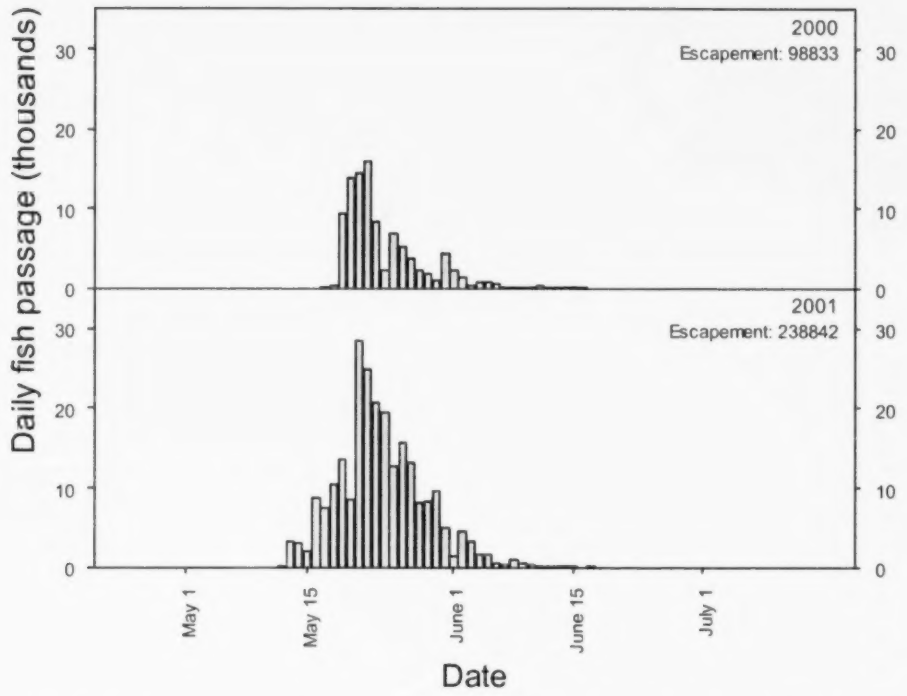

Figure 6. Daily escapement counts at the old White Rock fish ladder for the years 2000 and 2001. Visual counts were performed by field personnel and are total counts of the escapement run.

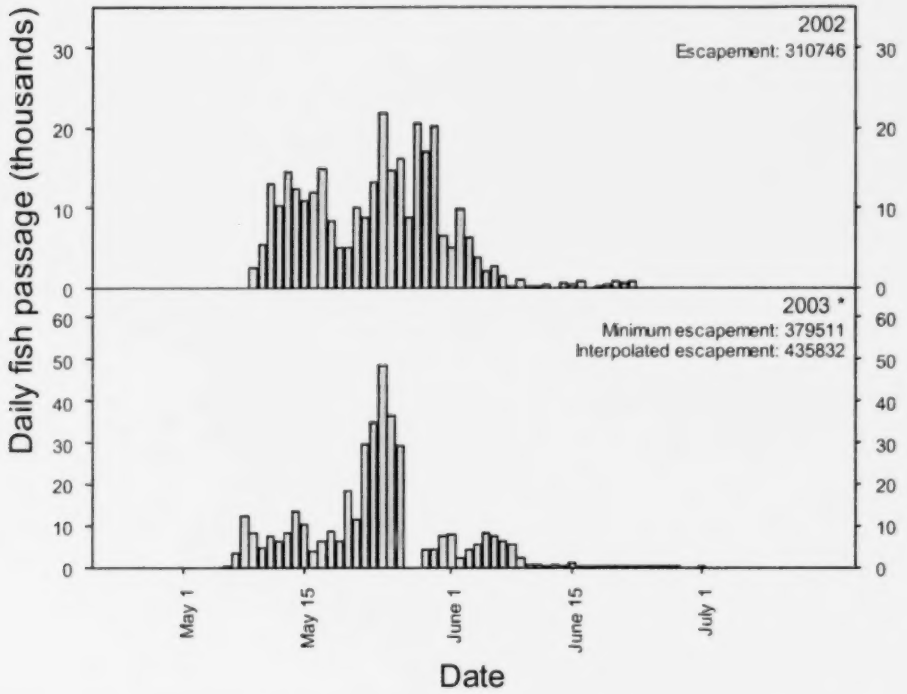

Figure 7. Daily estimates of the number of alewives passing through the new fishway or the years 2002 and 2003. Total estimated run size is given for each year. Counts from 2002 are total counts from video recordings, supplemented by hand counts, and represent the total escapement run. Total counts were done for 2003, however, intermittent malfunction resulted in the loss video counts throughout the run and missed days were estimated through linear interpolation. The precision of the interpolated 2003 escapement estimates are unknown.

Note change in the scale of y-axis for 2003.

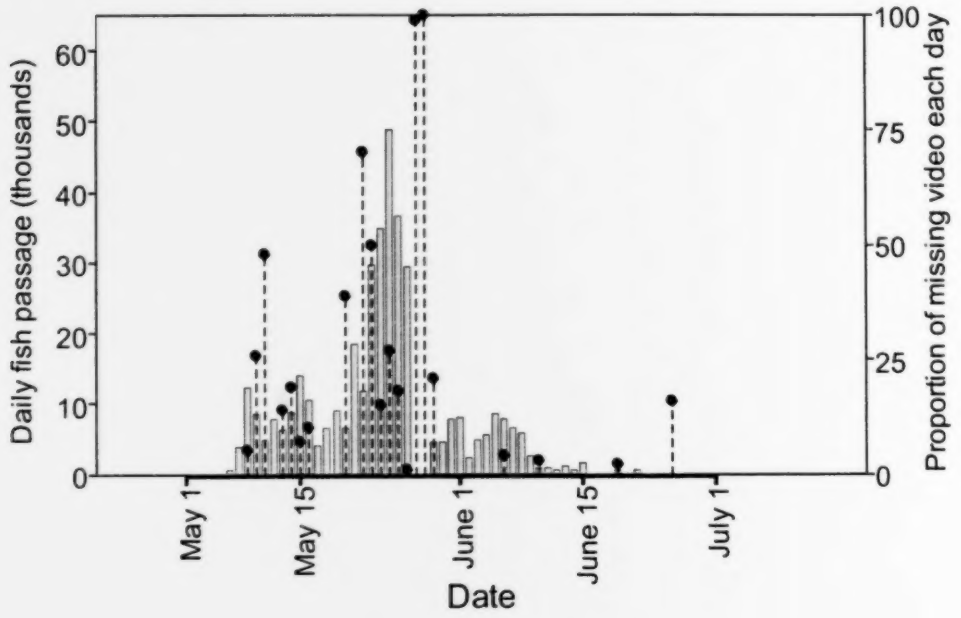

Figure 8. 2003 run with proportion of missing video marked on corresponding days. Bars = fish passage. Points and lines = proportion of missing video.

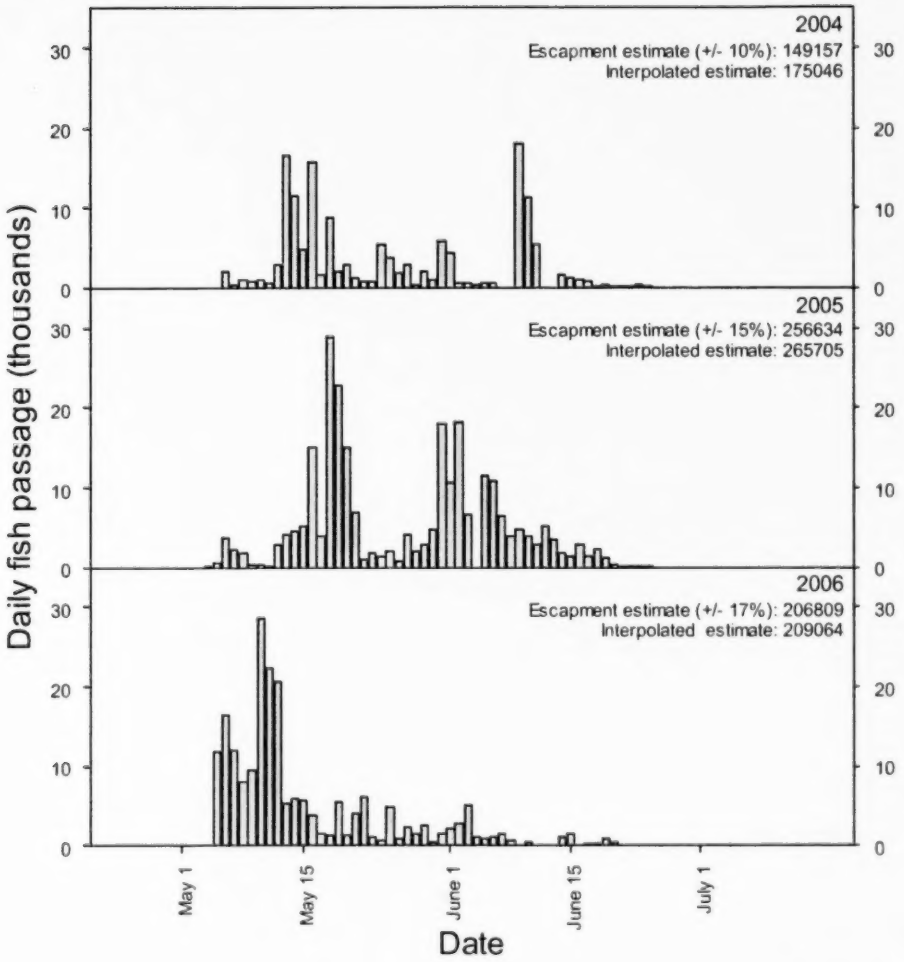

Figure 9. Daily estimates of the number of alewives passing through the new fishway for the years 2004 to 2006. Total estimated run size is given for each year. *A posteriori* subsampling was employed for these years to reach a precision of +/- 10%, +/- 15% and +/- 17% respectively. Linear interpolation was employed for all three years to account for missing days. The precision of interpolated estimates are unknown.

APPENDIX A

Gaspereau River Management Goal and Objectives (est. 2002)

Goal

- Within 5 years – achieve escapement of 400,000 gaspereau above the White Rock fishway

Objectives

- Close 1.8 km of river below new fishway to gaspereau fishing
- Provide additional 1 day per week close time (2130h each Tuesday to 0530h each Thursday) subject to on-going review for effectiveness
- Square nets to be removed from the water and chained and locked during the weekly close times
- DFO to provide additional monitoring and enforcement to ensure compliance with all restrictions
- Conduct in-season reviews to ensure progress and make necessary adjustments towards achieving the goal